Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh

22nd Annual Progress Report
August 2001

Chapter 12:
DSM2 Real-Time Forecasting System

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12 DSM2 Real-Time Forecasting System

12.1 Introduction

For several years, the Delta Simulation Model 2 (DSM2) has been used by DWR's Operations and Maintenance Environmental Compliance Section as a decision support tool. Real-time field data were combined with several different alternative forecast flow regimes and barrier configurations throughout the Delta through use of a series of pre-processing scripts. Observed tidal data from Martinez were combined with astronomical tidal data when running DSM2-HYDRO. DSM2-QUAL and/or DSM2-PTM then used the hydrodynamics modeled by HYDRO to explore a series of "what if" questions related to the alternative flow regimes and/or barrier configurations.

These DSM2 "Real-Tide" studies were performed on an *ad hoc* basis. Typically, DSM2 was used to answer short-term questions in a short amount of time. For example, project operators or biologists have relied on these studies to answer some of the following questions (the principal DSM2 module(s) used to answer these questions is(are) listed in parenthesis).

- How will south Delta stage change based on the operation of the South Delta Temporary Barriers? (HYDRO)
- What impact does the timing of the Clifton Court Forebay gates have on South Delta stage? (HYDRO)
- Will there be a carriage water cost associated with a water transfer? (HYDRO & QUAL)
- What impact will closing or opening the Delta Cross Channel have on Central Delta salinity? (QUAL)
- Will changing upstream reservoir releases exceed Central Delta water quality standards? (QUAL)
- Will reducing exports change the location of X2? (QUAL)
- Can opening the flap gates on the South Delta Temporary Barriers increase fish survival? (PTM)

These and many other questions are often the focus of multi-agency and multi-disciplinary meetings charged with the responsibility to find solutions to water-related problems associated with the Delta. Unfortunately, the solution to one water supply, quality, or environmental need may aggravate another water supply, quality, or environmental need. While DSM2 Real-Tide studies have allowed several alternatives to be explored within the framework of the same initial conditions, the scripts used to pre-process the alternatives for each of the three DSM2 modules were difficult to use under the short time constraints. Thus, time that could have been spent creating alternative scenarios that could better address a host of questions was instead spent on creating a single base case scenario.

In response to these needs, the following groups within DWR have worked to create a new set of scripts and procedures designed around the existing DSM2 Real-Tide simulations.

- Division of Operations and Maintenance Project Operations Planning Branch
- Environmental Services Office Suisun Marsh Planning Section
- Environmental Services Office Interagency Information System Services Section
- Office of SWP Planning Temporary Barriers Project and Land Management Section
- Office of SWP Planning Delta Modeling Section

DSM2-HYDRO, QUAL, and PTM have not been changed, but the steps involved in linking the DSM2 modules have been simplified to such an extent that the new DSM2 application is now called the "DSM2 Real-Time Forecasting System".

This chapter will cover the development and use of the DSM2 Real-Time Forecasting System. Its focus will not be on the technical theory behind the tools used in this system, but instead on the use of these tools as a comprehensive modeling system. A more detailed explanation dealing with the technical improvements related to filling in and forecasting DSM2 stage at Martinez was covered by Ateljevich (2000a). More detailed descriptions of the technical issues related to both the initial water quality conditions used by QUAL were also described by Ateljevich (2000b). The method used to fill in missing periods of EC at the downstream Martinez boundary is discussed in Chapter 11.

Complete step-by-step guides designed to lead numerical modelers through every step involved in a DSM2 forecast are also available at http://modeling.water.ca.gov/delta/real-time/. This on-line document was designed to be flexible enough so that it could be easily updated and used by numerical modelers in order to ensure quality in their forecast runs. It was also designed on the theory that a modeler familiar with the DSM2 Real-Time Forecast System could easily navigate through short checklists (available at http://modeling.water.ca.gov/delta/real-time/real-time.html), while new users or the end users of the system (typically decision makers) could follow links to pages covering greater detail to answer any specific questions they might have. This report will not attempt to recreate this documentation.

12.2 Background

As discussed above, various groups within DWR have been combining real-time field observations with forecast Delta operations in DSM2 in order to forecast hydrodynamic, water quality, and particle fate within the Delta on an *ad hoc* basis for several years. In November 1999, an interagency recommendation was made to close the Delta Cross Channel gates in order to protect out-migrating juvenile salmon smolts.[1] The closure of the Delta Cross Channel gates roughly corresponded with the neap tide. Water quality levels in the Delta were already

[1] In November the Delta Cross Channel gates may either be opened or closed.

approaching several of the water quality standards, and by early December 1999, the Rock Slough Chloride standard was violated.

In mid December 1999, it was recommended by the CALFED Ops Data Assessment Team (DAT) to operate the Delta Cross Channel gates on a tidal basis in order to offer some protection to any remaining out-migrating salmon, while allowing some fresher Sacramento River water to pass through the Delta Cross Channel in order to improve Central Delta water quality conditions. Due to the need to make a quick decision, DSM2 was used to forecast water quality in the Central Delta based on this proposed operation of the Delta Cross Channel gates. Planned upstream inflows and South Delta export rates were input into DSM2. However, due to large periods of missing boundary stage data, the DSM2 simulations were not finished in time to aid in the decision regarding the operation of the Delta Cross Channel gates.

While reviewing the December 1999 decisions, the Bay Delta Modeling Forum (BDMF) requested that this late November - December period be modeled by DSM2 and the subject of a special BDMF workshop[2]. Several other alternative scenarios were investigated by DSM2 at this same time in an attempt to model what other options could have been implemented in order to protect Central Delta water quality. The results of these DSM2 simulations were presented at this BDMF workshop in February 2000, where it was agreed by DWR that the use of DSM2 should be improved in order to provide decision makers with a variety of alternative forecasts in a timely fashion.

A DWR project work team consisting of members from the groups listed in the introduction began working on solving both the technical and institutional problems involved in creating a DSM2 Real-Time Forecasting System. The Division of Operations and Maintenance Project Operations Planning Branch agreed to provide forecast information (including the information necessary to construct several alternatives) in addition to funding part of the development of the system. The Office of SWP Planning (OSP) Delta Modeling and Environmental Services Office (ESO) Interagency Information System Services Sections both took the lead in developing the tools necessary to address many of the technical problems associated with both the pre-processing and running of DSM2. The ESO Suisun Marsh Planning Section developed a visual way to quickly share the modeling results to a wide range of decision-makers. The Division of Operations and Maintenance Operations Planning Branch and the OSP Temporary Barriers Project and Land Management Section represented two of the end users of the system.

A prototype of the DSM2 Real-Time Forecast System was in intermittent use by DWR Operations and Maintenance by the fall of 2000. In conjunction with the IEP and CALFED funded Delta Cross Channel investigations in the Fall of 2000, DSM2 was used to forecast the impact of several different Delta Cross Channel gate operations well in advance of the actual operations. The primary concern at the time was “what impact would tidal operations of the Delta Cross Channel have on Central Delta water quality?”. Based on these DSM2 forecasts, which did not show a marked increase in Central Delta salinity, the IEP / CALFED investigations continued without any major changes.

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[2] The focus of Bay Delta Modeling Forum workshop in February 2000 was to review the ability of the various models used by the San Francisco Bay-Delta community to be used as Real-Time decision tools. DSM2 was just one of the models presented in the workshop.

Although work on improving the DSM2 Real-Time Forecast System continues, the system is currently in use by Operations and Maintenance, the Suisun Marsh Planning Section, and the Delta Modeling Section.

12.3 Real-Time Modeling Forecast Processes

Any real-time modeling forecast system can be described as having five essential processes that follow a simple flow chart (see Figure 12-1). The raw data and model results are represented by trapezoids in the flow chart. The remaining three processes include pre-processing the data, running the model, and post-processing the results. These middle three processes will need to be repeated for each alternative scenario that is run. However, since each alternative should focus on a single permutation, the time spent constructing and reviewing the alternatives typically will be no longer than the time spent preparing the base case scenario. More detailed discussions of how these general steps are integrated into DSM2 are discussed below.

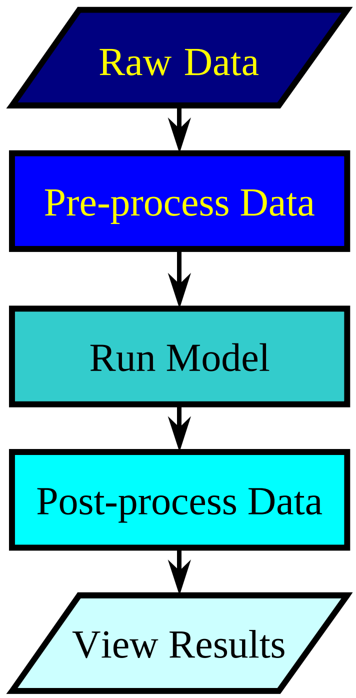


Figure 12-1: Flow Chart of a Numerical Modeling Forecast System.

12.3.1 Raw Data

Real-time raw data is often of highly variable quality and a host of problems arise simply in collecting and storing this data. If the forecast system is used on a regular basis, the questions frequently asked of the model will be known in advance and the decision of what data to actually use can be standardized or automated. This will save time in collecting the raw data. Both observed field data and forecast inflows must be collected. DWR Operations and Maintenance provide the forecast inflows.

The observed hydrodynamic and water quality data are retrieved from the IEP Data Storage System (DSS) database, located at http://wwwiep.water.ca.gov/dss/. This is accomplished by using VPlotter, which was developed by the Section in order to automate DSS data retrieval and allow users to quickly plot any DSS data (Sandhu 2000). The user only needs to set a time window (a period of interest) in which to download all the data. Before saving the raw data to a local DSS file, the quality of the data can first be checked by graphing the raw data for the time window selected. A screen shot of the VPlotter graphical user interface (GUI) being used to retrieve raw data is shown in Figure 12-2. A more detailed description of how to actually go through and retrieve raw DSS data using VPlotter is available at http://modeling.water.ca.gov/delta/real-time/retriever.html.

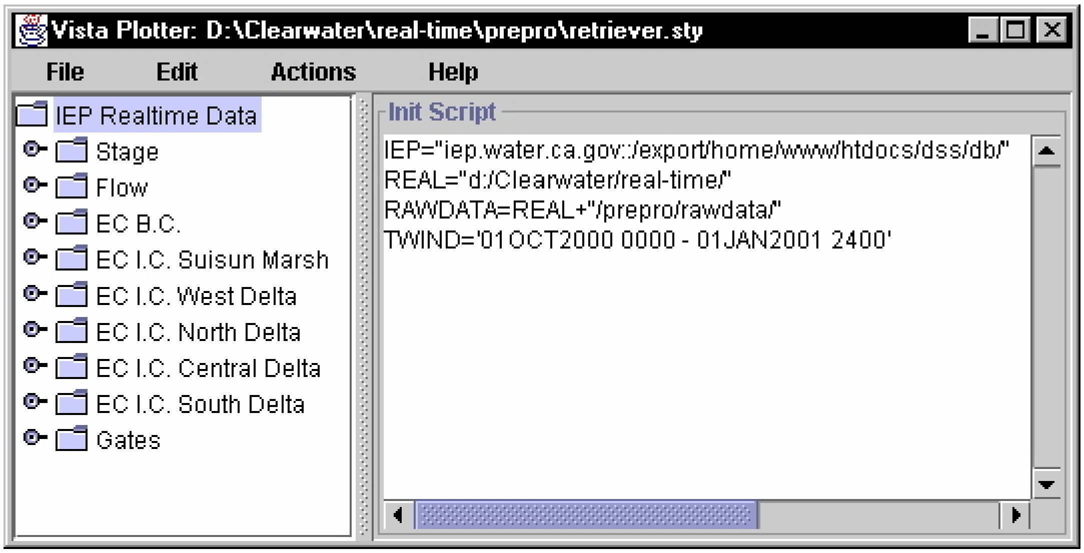


Figure 12-2: VPlotter DSS Data Retrieval GUI.

12.3.2 Pre-processing

Obviously, raw data can not be used without first undergoing a screening procedure. In the case of real-time data, such a pre-processing step often represents the first time that a human has actually spent time looking at the data, thus the time spent preparing the data for a model run is often greater than what would be done in a planning model or in a historical simulation. Judgement must be used to filter out unacceptable data as well as to resolve any problems that arise from missing data.

As discussed above, when raw IEP DSS data are locally downloaded, it can first be graphically viewed as part of a quality control procedure. The raw data retriever process described above was designed to look at and retrieve several different DSS paths for the same location. An example of the VPlotter GUI doing this for the Sacramento River is shown below in Figure 12-3. Each DSS path represents either data collected by a different agency or a different time step. Predetermined standard paths to use in a real-time forecast are listed in Tables 12-1, 12-2, and 12-3 below. Any time the raw data in one of these standard paths is either missing large amounts of data or otherwise can not be cleaned up, one of the other alternate DSS paths for the same location can be used, instead. Any changes made to this list of standard paths will be reflected in the on-line documentation, http://modeling.water.ca.gov/delta/real-time/faq.html#ForePaths.

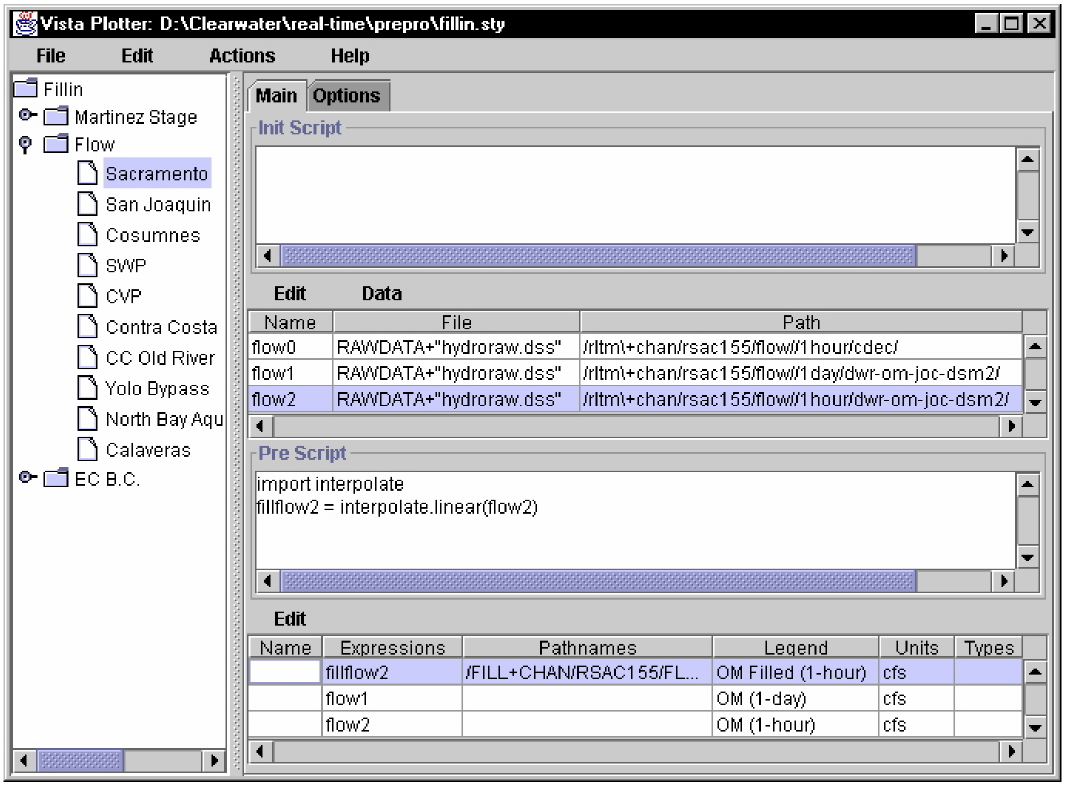


Figure 12-3: Retrieving Multiple Time Series for Same Location.

Table 12-1: Standard IEP DSS Hydrodynamic DSM2 Real-Time Inputs.

Input	**Type**[3]	**IEP DSS Path**
Calaveras River	Flow	/RLTM+CHAN/RCAL009/FLOW//1HOUR/DWR-OM-JOC-DSM2/
Contra Costa Canal (Rock Slough)	Diversion	/RLTM+CHAN/RCAL009/FLOW//1HOUR/DWR-OM-JOC-DSM2/
Contra Costa Old River (Los Vaqueros)	Export	/RLTM+CHAN/ROLD034/FLOW-EXPORT//1DAY/DWR-OM-JOC-DSM2/
Cosumnes	Flow	/RLTM+CHAN/RCSM075/FLOW//1HOUR/DWR-OM-JOC-DSM2/
Central Valley Project	Export	/RLTM+CHAN/CHDMC004/FLOW-EXPORT//1DAY/DWR-OM-JOC/
Mallard Island	Stage	/RLTM+CHAN/RSAC075/STAGE//1HOUR/CDEC/
Martinez	Stage	/RLTM+CHAN/RSAC054/STAGE//1HOUR/CDEC/
Mokelumne River	Flow	/RLTM+CHAN/RMKL070/FLOW//1HOUR/DWR-OM-JOC-DSM2/
North Bay Aqueduct	Export	/RLTM+CHAN/SLBAR003/FLOW-EXPORT//1DAY/DWR-OM-JOC/
Sacramento River	Flow	/RLTM+CHAN/RSAC155/FLOW//1HOUR/DWR-OM-JOC-DSM2/
San Joaquin River	Flow	/RLTM+CHAN/RSAN112/FLOW//1HOUR/DWR-OM-JOC-DSM2/
S.F. Golden Gate	Stage	/RLTM+CHAN/SHWSF001/STAGE//1HOUR/NOAA/
State Water Project	Export	/RLTM+CHAN/CHSWP003/EXPORT//1DAY/DWR-OM-JOC/
Yolo Bypass	Flow	/RLTM+CHAN/BYOLO040/FLOW//1HOUR/DWR-OM-JOC-DSM2/

[3] Types of hydrodynamic inputs include flow, export/diversion, and stage.

Table 12-2: Standard IEP DSS Water Quality DSM2 Real-Time Boundary Inputs.

Input	Type	IEP DSS Path
Mallard Island	EC	/RLTM+CHAN/RSAC075/EC//1HOUR/DWR-OM-JOC-DSM2/
Martinez	EC	/RLTM+CHAN/RSAC054/EC//1HOUR/CDEC/
Sacramento	EC	/RLTM+CHAN/RSAC142/EC//1HOUR/CDEC/
San Joaquin	EC	/RLTM+CHAN/RSAN112/EC//1HOUR/DWR-OM-JOC-DSM2/

Table 12-3: Standard IEP DSS Water Quality DSM2 Real-Time Initial Condition Inputs.

Input	Type	IEP DSS Path
Antioch	EC	/RLTM+CHAN/RSAN007/EC//1HOUR/CDEC/
Bacon Island	EC	/RLTM+CHAN/ROLD024/EC//1HOUR/DWR-OM-JOC-DSM2/
Beldon's Landing	EC	/RLTM+CHAN/SLMZU011/EC//1HOUR/DWR-OM-JOC-DSM2/
Cache Slough	EC	/HIST+CHAN/SLCCH016/EC//1HOUR/USBR-CVO/
Collinsville	EC	/RLTM+CHAN/RSAC081/EC//1HOUR/DWR-OM-JOC-DSM2/
Central Valley Project	EC	/RLTM+CHAN/CHDMC004/EC//1HOUR/DWR-OM-JOC-DSM2/
Emmaton	EC	/RLTM+CHAN/RSAC092/EC//1HOUR/DWR-OM-JOC-DSM2/
Farrar Park (Dutch Slough)	EC	/HIST+CHAN/SLDUT009/EC//1HOUR/USBR-CVO/
Goodyear Slough	EC	/RLTM+CHAN/SLGYR003/EC//1HOUR/DWR-OM-JOC-DSM2/
Green's Landing	EC	/HIST+CHAN/RSAC139/EC//1HOUR/USBR-CVO/
Holland Cut	EC	/RLTM+CHAN/ROLD014/EC//1HOUR/DWR-OM-JOC-DSM2/
Jersey Point	EC	/RLTM+CHAN/RSAN018/EC//1HOUR/DWR-OM-JOC-DSM2/
Middle River @ Hwy. 4	EC	/HIST+CHAN/RMID023/EC//1HOUR/USBR-CVO/
Middle River @ Tracy Blvd.	EC	/RLTM+CHAN/RMID027/EC//1HOUR/CDEC/
Piper Slough @ Bethel Island	EC	/RLTM+CHAN/SLPPR003/EC//1HOUR/DWR-OM-JOC-DSM2/
Pittsburg	EC	/RLTM+CHAN/RSAC077/EC//1HOUR/USBR-CVO/
Prisoner's Point	EC	/RLTM+CHAN/RSAN037/EC//1HOUR/CDEC/
Port Chicago	EC	/RLTM+CHAN/RSAC064/EC//1HOUR/DWR-OM-JOC-DSM2/
Rio Vista	EC	/RLTM+CHAN/RSAC101/EC//1HOUR/CDEC/
Rock Slough	EC	/RLTM+CHAN/CHCCC006/EC//1HOUR/DWR-OM-JOC-DSM2/
San Andreas Landing	EC	/HIST+CHAN/RSAN032/EC//1HOUR/USBR-CVO/
Staten Island	EC	/HIST+CHAN/RSMKL008/EC//1HOUR/USBR-CVO/
Sunrise Club	EC	/RLTM+CHAN/SLCBN002/EC//1HOUR/DWR-OM-JOC-DSM2/
Volanti	EC	/RLTM+CHAN/SLSUS012/EC//1HOUR/DWR-OM-JOC-DSM2/

Separate procedures have been developed to pre-process stage, flow, and water quality data. These procedures are described in detail below.

12.3.2.1 Stage

Correctly characterizing stage at Martinez is critical when attempting any DSM2 simulation. Ateljevich (2000a) discussed the theory behind filling in and forecasting stage at Martinez. Using Jython, a script that replicates the Python scripting language but is written in Java in order to directly incorporate existing Java code, Ateljevich designed an automated three-step tool in VPlotter to quickly characterize stage at Martinez. A step-by-step detailed description of how to use this tool can be found at http://modeling.water.ca.gov/delta/real-time/fillin.html#3.1.

The first step uses Jython scripts within a standard VPlotter session to calculate the residual differences between observed stage at three locations, and each location's calculated astronomical stage. These residuals are then used in a vector autoregressive model to fill in missing residual values and forecast the Martinez residual. This is the most time-intensive step involved in pre-processing stage, and typically takes under 5 minutes to fill in and forecast up to two months of tidal data at Martinez.

The quality of the forecast is reviewed in the second step by comparing the newly created filled-in and forecast Martinez stage with the observed values. After verifying that the new stage characterization represents a good fit with the historical data and appears to follow a spring-neap cycle, the new data are saved to a working input file. A final check is made to verify that the correct data were saved in the working input file in the third step by once again graphing the forecast stage data with the observed values. An example of the Martinez stage fill-in verification is shown below in Figure 12-4.

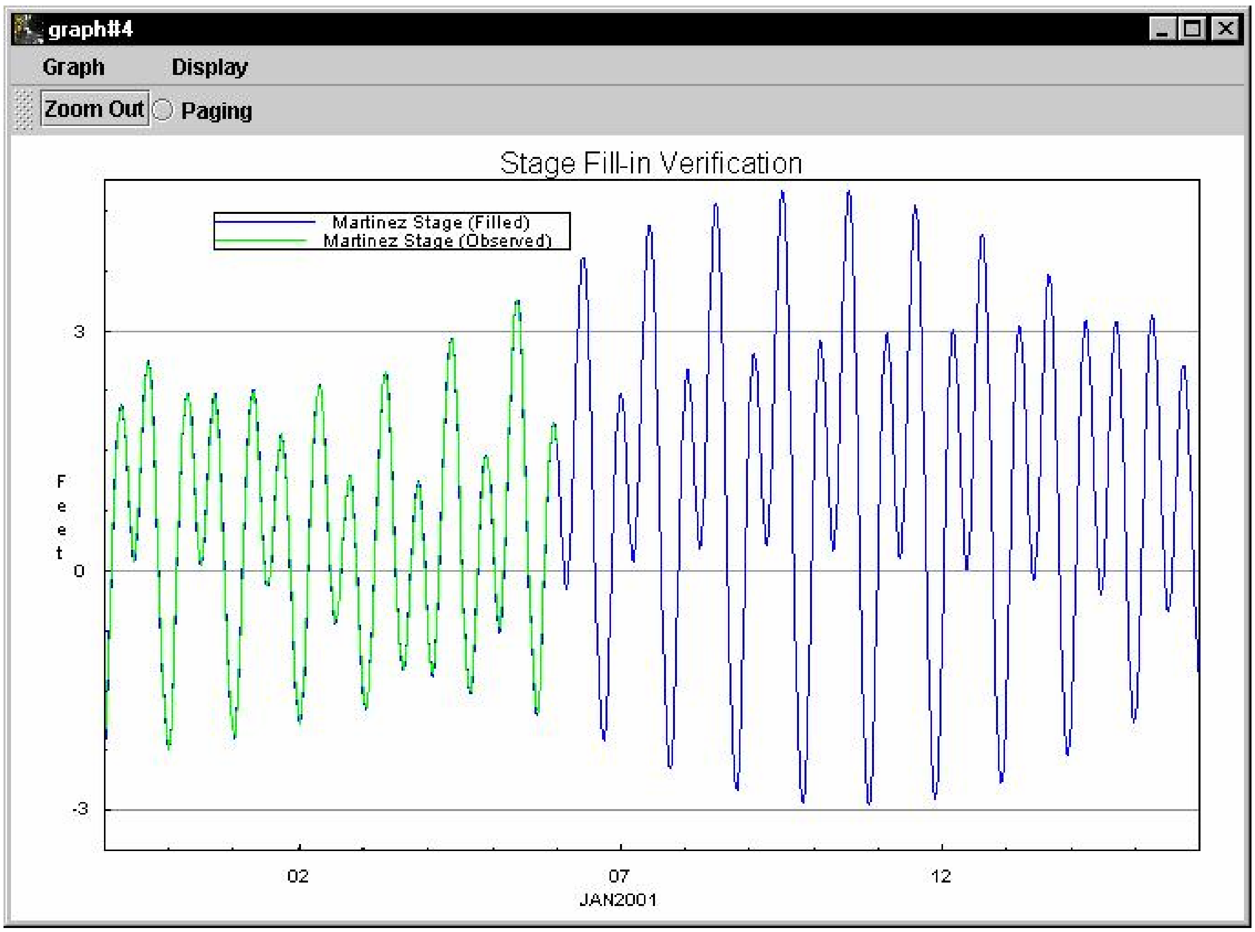


Figure 12-4: Martinez Stage Verification.

12.3.2.2 Flow

Historical and forecast rim inflows and export/diversion flows are pre-processed in different ways. The basic concepts behind pre-processing both the historical and forecast flow data are described below. The process for filling in historical flow values is described in detail at http://modeling.water.ca.gov/delta/real-time/fillin.html#3.2. The process for creating forecast flow data is described in detail at http://modeling.water.ca.gov/delta/real-time/foreform.html.

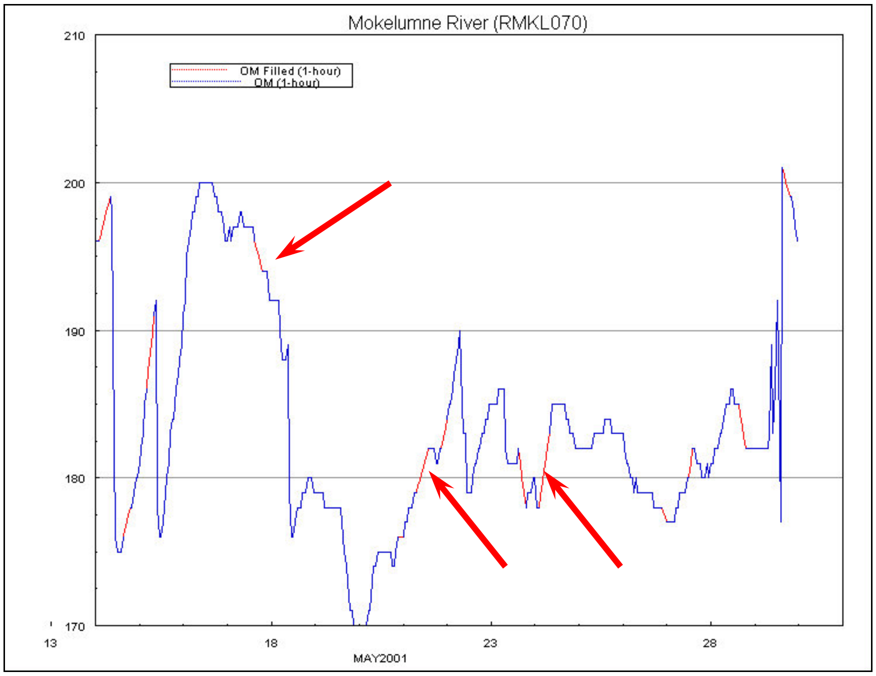


Figure 12-5: Example of Filling in Historical Flow Data (Without Tidal Influence).

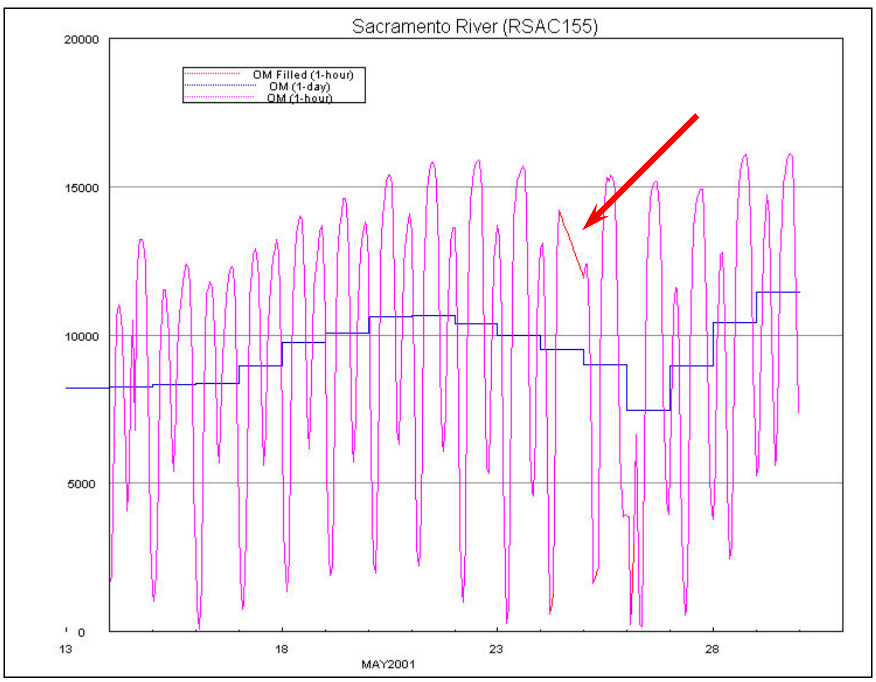


Figure 12-6: Example of Filling in Historical Flow Data (With Tidal Influence).

The historical raw flow data are read in using the same VPlotter script that was used when filling in and forecasting Martinez stage. Missing historical flow data are filled in using a simple linear regression, as is shown above in Figures 12-5 and 12-6. This approach is ideal for filling in flows that are only missing data in short time periods (on the order of a few hours) and flows that do not have a strong tidal influence, as is shown in Figure 12-5 for the Mokelumne River. However, when the tidal influence is strong, a simple linear regression is not adequate to capture the flood-ebb tides within the missing data, as is shown in Figure 12-6 for the Sacramento River.

Though a linear regression can not capture the flood-ebb tidal cycle that is present on the Sacramento River, during periods of high flow (over 25,000 cfs) this tidal signal will not be present. The use of linear regression to fill in missing data in periods of high flow will be adequate to characterize the flow on the Sacramento River. It has been suggested that a system of priorities similar to other DSM2 applications be used. This could be done by filling in missing hourly data with the daily average data (which also could be missing in some cases) or data from other providers. Moving from an hourly time series to a daily average may, in some cases, result in a jump that is not that much different from the discontinuity between the tidally influenced hourly data and the linear regression fill in values. Moving from data provided by one agency to another may avoid some of these issues, but it is important to remember that the first priority data used by VPlotter were originally found to be of higher quality than the sources at the same location. In fact, some data providers regularly shift their data to reflect time changes associated with daylight savings time. DSM2 does not account for the shift to and from daylight savings time, so if necessary, additional pre-processing steps have to be added when data that is out of phase with the model and other data are being used. The process for making these changes has been outlined in the on-line user's documentation. However, it is important to remember that the goal of pre-processing the historical flow data is to provide a compromise between using appropriate model inputs and being able to produce a series of simulations in a short time frame. Since DSM2 is being used only as a trend analysis tool in this application, it is actually recommended to avoid mixing data from different DSS sources.

Forecast flow data representing both the planned operations of the State Water Project and Central Valley Project and possible alternative operations are created by project operators and decision makers. These forecasts are converted from a MS Excel spreadsheet into DSS for use in DSM2 through a series of MS Access GUIs. This system is referred to as the MS Access Forecast Form (see Figure 12-7 below for the opening page of the form).

As with the Vplotter scripts, the MS Access Forecast Form was designed to quickly convert forecast rimflow, export and diversion, and Net Delta Outflow Index information into a format that can be used in DSM2. The forecast data are reported as daily averages. Again, detailed instructions of how to use the form to create both base forecasts and to alter the raw forecast data in order to create alternative scenarios are available on-line at http://modeling.water.ca.gov/delta/real-time/foreform.html. In addition to creating the necessary flow data to run forecasts, the same form can be used to update the operation of the South Delta Barriers, including the Old River at the head of the San Joaquin River, Middle River, Grant Line Canal, and Old River near the Delta Mendota Canal intake barriers. The forecast gate operations use minute-based time steps; thus, complex tidal operations can be created using the MS Access Forecast Form.

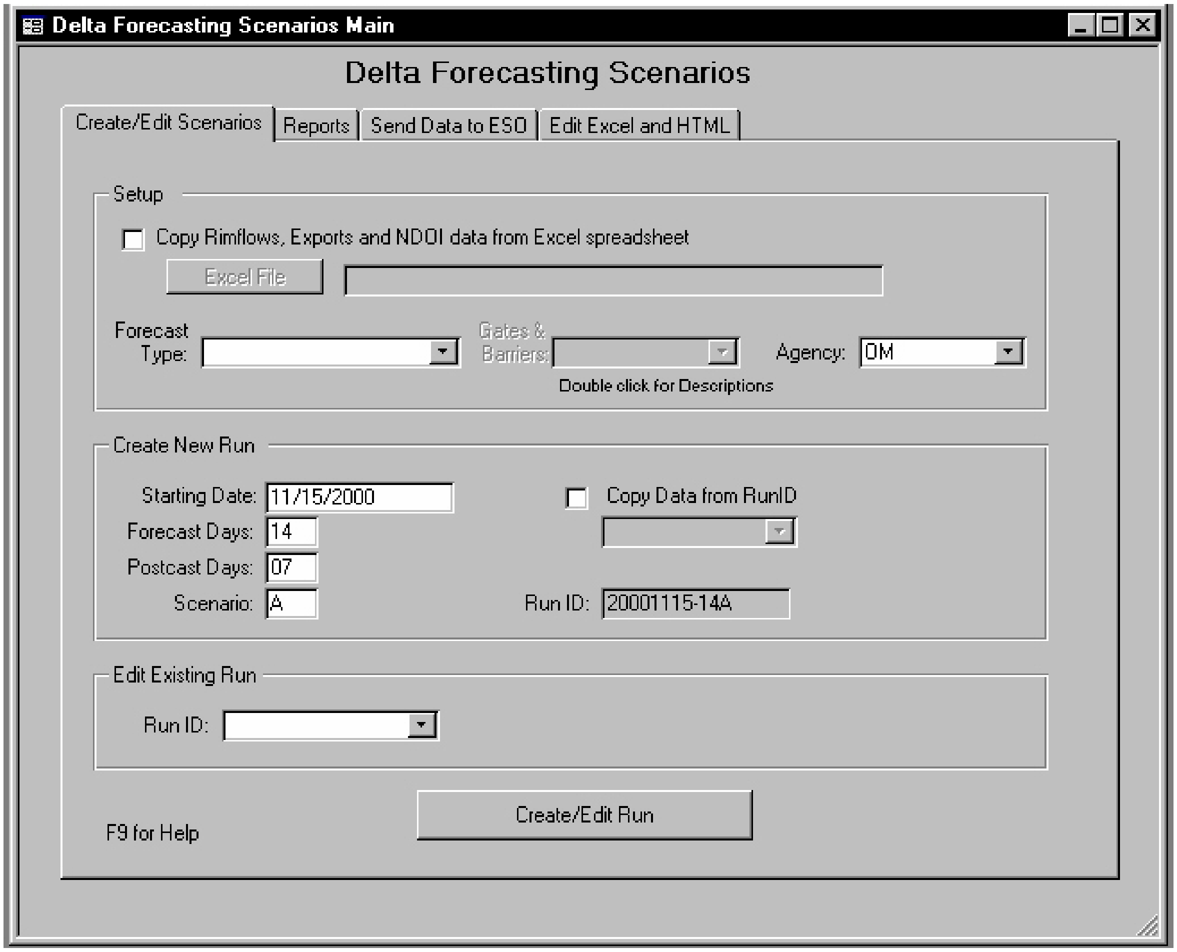


Figure 12-7: MS Access Forecast Form.

To keep track of different scenarios, a YYYYMMDD-XXS naming convention has been adopted. The first part of the name (YYYYMMDD) marks the start date of the forecast, t_f, the second part (XX) identifies the length of the forecast, and the third part (S) represents the actual scenario. By using this scenario naming convention, it is necessary to change only the main input file for each DSM2 module (HYDRO, QUAL, and PTM). Furthermore, unique naming conventions prevent old forecast data from accidentally being used.

12.3.2.3 Water Quality

Filling in and forecasting Martinez EC requires a complete forecast of the NDO Index. A more detailed description behind the theory of this process is discussed in Chapter 11. Detailed instructions how to use VPlotter to fill in and forecast Martinez EC are located at http://modeling.water.ca.gov/delta/real-time/ecdata.html. The basic process is similar to how Martinez stage is filled in and forecast, in that a series of three quick steps are used. First, observed stage, EC, and NDOI are taken from the raw and forecast data. Next this raw data are graphed for visual inspection, as is shown below in Figure 12-8. If the data are judged to represent a good fit to the observed Martinez EC and generally show an appropriate forecast response, the filled-in data are saved to a local data file for use by DSM2. Finally, the data are again plotted in a verification step in order to ensure that the correct data will be used during DSM2 simulations.

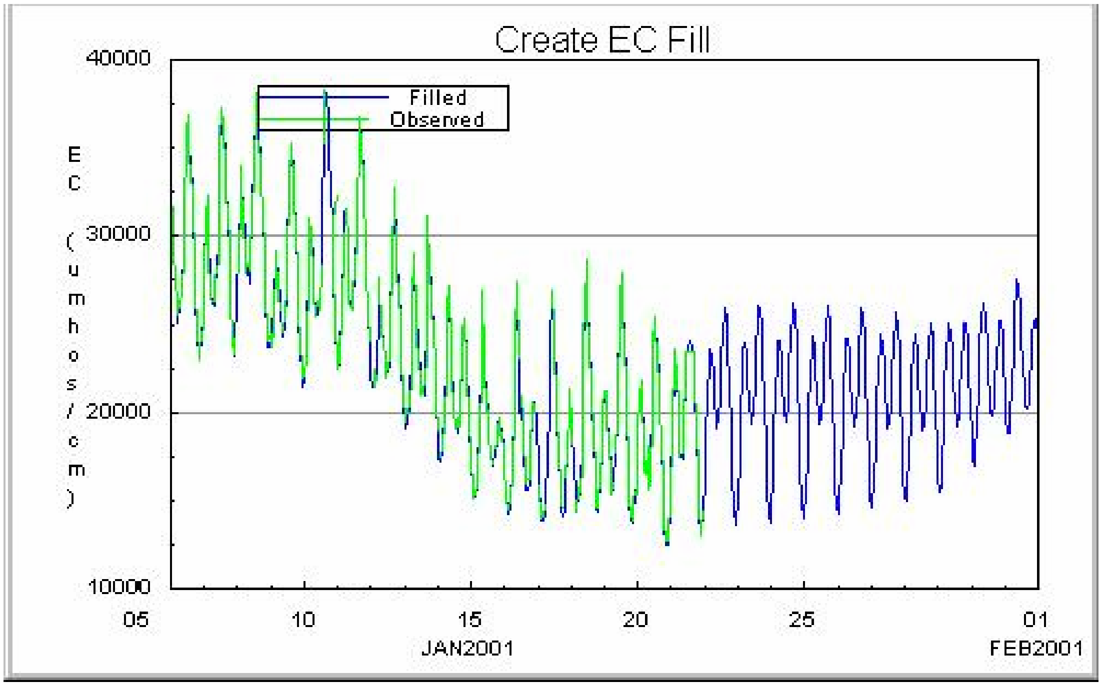


Figure 12-8: Martinez EC Verification.

Missing EC data for both the Sacramento and San Joaquin rivers are filled in using the same linear regressions that were used to fill in missing flow data. The EC for these two locations does not show a response to the flood-ebb tidal signal that was shown to influence the Sacramento River flow during periods of low flow. The EC values for the other major DSM2 rim boundaries are held at fixed concentrations because there are no regular time series data for these locations.

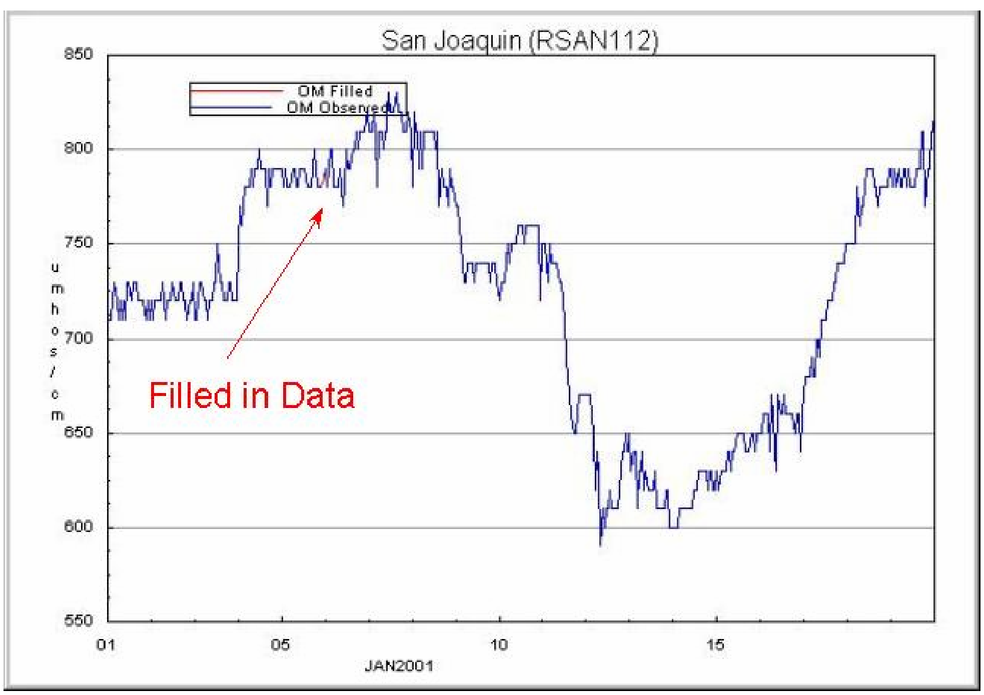


Figure 12-9: Filling in Rim Boundary EC.

Table 12-3 is used to generate the initial salinity conditions within the Delta in a process commonly referred to as "warm start". A detailed explanation of the theory behind water quality warm start can be found in Ateljevich (2000b). The process of creating warm start initial water quality conditions for the DSM2 Real-Time Forecast System is relatively simple. Two Jython scripts are used to take advantage of QUAL's multi-constituent capabilities to create initial conditions for the forecast QUAL simulations. This scripts take between 10 and 20 minutes to run. Since only historical data are used, the initial conditions created for the base forecast can be used for all the alternative scenarios. A more detailed explanation of how to actually run these scripts is located at http://modeling.water.ca.gov/delta/real-time/warmstart.html.

12.3.3 Running DSM2

The shortest process of the DSM2 Real-Time Forecasting System is actually running DSM2-HYDRO, QUAL, and PTM. Two Jython scripts were created to run HYDRO and QUAL. PTM is run through use of a batch file. However, before running any of the DSM2 modules, a few of the input files need to be updated. Complete instructions describing which input files need to be updated and how to actually run the scripts and batch file for HYDRO, QUAL, and PTM are located at http://modeling.water.ca.gov/delta/real-time/running.html.

DSM2 needs to be run once for each scenario. Editing the input files and running HYDRO and QUAL for a single 60-day simulation typically takes less than 20 minutes. Depending on what is being modeled with PTM, a 60-day simulation will take between 20 minutes and 4 hours to run.

12.3.4 Post-processing

To ensure quality in the forecasts, a few VPlotter scripts similar to the script that retrieves raw data are used to visually compare model output with (1) the model input and (2) any observed real-time field data. The observed real-time field data is taken from the IEP DSS database. Two examples comparing model results to the observed real-time data are shown in Figures 12-10 and 12-11. Though there are no observed data during the forecast periods, it is still useful to look at the model results into the forecast period. This is shown in Figure 12-11, in which both the instantaneous and tidally filtered stages at Antioch are displayed for the entire simulation period.

Part of the post-processing procedure is to check the model results in locations near the area of interest for each study. For example, if a forecast was designed to investigate the operations of the South Delta Temporary Barriers, then DSM2 results in the South Delta should be the focus of any comparisons. Unfortunately, the number of real-time telemetered flow and stage locations in the Delta is limited, thus it is impossible to always use recent field data to check the quality of forecast results. In the cases where there are no nearby field data, it is still useful to use the post-processing scripts to examine the model results before publishing the results. The main question that should be asked of any location is "do these model results make sense?".

It is equally important to compare alternate scenario results to the base case while checking the quality of the forecast. Again using the South Delta Temporary Barrier example, if an alternate scenario involved the removal or installation of a barrier, there should be some difference in the hydrodynamic results between this alternative and the base cases. If this difference does not appear shortly after the planned alternative operation when looking at the results, there is an error in either the base case or alternative scenario.

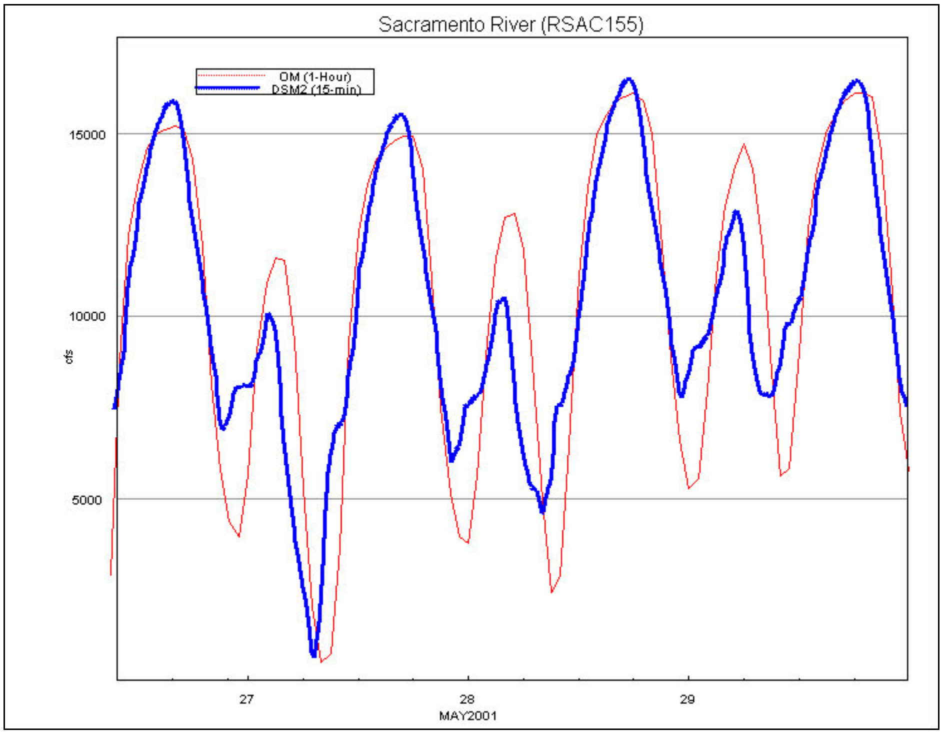


Figure 12-10: Comparison of Modeled Flow versus Observed Flow at Freeport.

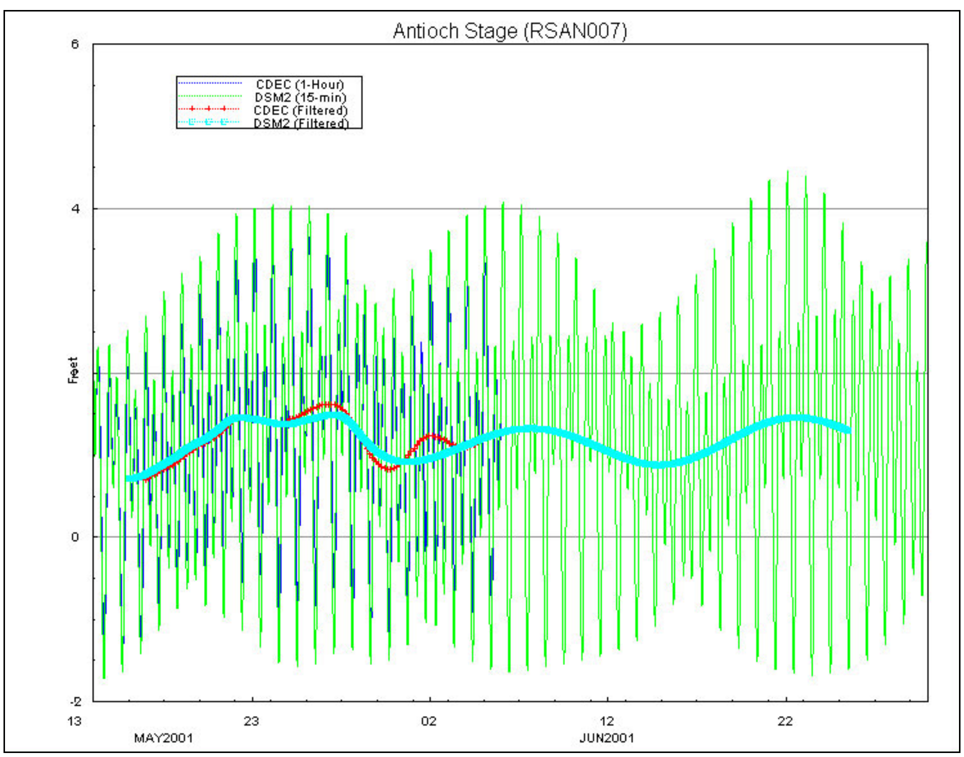


Figure 12-11: Comparison of Modeled Stage versus Observed Stage at Antioch.

When there are either large differences between the simulated results and the field results, or there are unexpected patterns between the base case and alternative scenarios, it is the job of the modeler to review his/her input files. A common mistake (such as forgetting to change an environment variable that is used to point to the most recent forecast data in the DSM2 input files) can quickly be corrected, and the DSM2 forecast simulations should be rerun. While the pre-processing tools described above are easy to use, in the case of a barrier configuration, it is possible that an incorrect time was entered while preparing the forecast. Mistakes similar to these require that the raw data be pre-processed again a second time. Since the preprocessing steps were designed with speed in mind, it is recommended that the entire processing procedure be started over again.

Finally, one way to prevent accidentally pointing to old forecast data is to archive previous forecast input and output data, then delete all of the locally saved raw and processed data files. It is recommended that old forecasts be burned to a CD-ROM. If an end user wishes to revisit an older forecast, the results will be available on-line (as will be discussed below) or he/she can access this information from the CD-ROM.

12.3.5 On-line Output

The last and most visible step involved in the DSM2 Real-Time Forecast System focuses on efficiently presenting the results of the model in a format that is both easily accessible to all the end users and in a way that permits a wide range of end users to be able to interpret the results. One of the scripts used to view the model results in the post-processing step discussed above is also used to convert the model results to a series of images. These images are then stored on an IEP web site dedicated to presenting DSM2 forecast results. This site is located at http://www.iep.water.ca.gov/cgi-bin/dsm2pwt/realtime/realtime.pl.

An example of the entry Web page where results can be viewed is shown below in Figure 12-12. At the time of this writing, all of the on-line results pages were still being worked on, as end users (including both operators and biologists) are currently providing input into what would be a more useful way to select forecasts, alternative scenarios, and view these results. The underlying design philosophy behind the continuing development of any forecast output display is that any end user should be able to navigate through the forecast results easily. HYDRO and QUAL results are shown together and can be accessed through an interactive map of the Delta, as is shown in Figure 12-13. PTM results can be viewed either through a series of static plots based on a map of the Delta or through a series of animations. Users must select which two scenarios they wish to view.

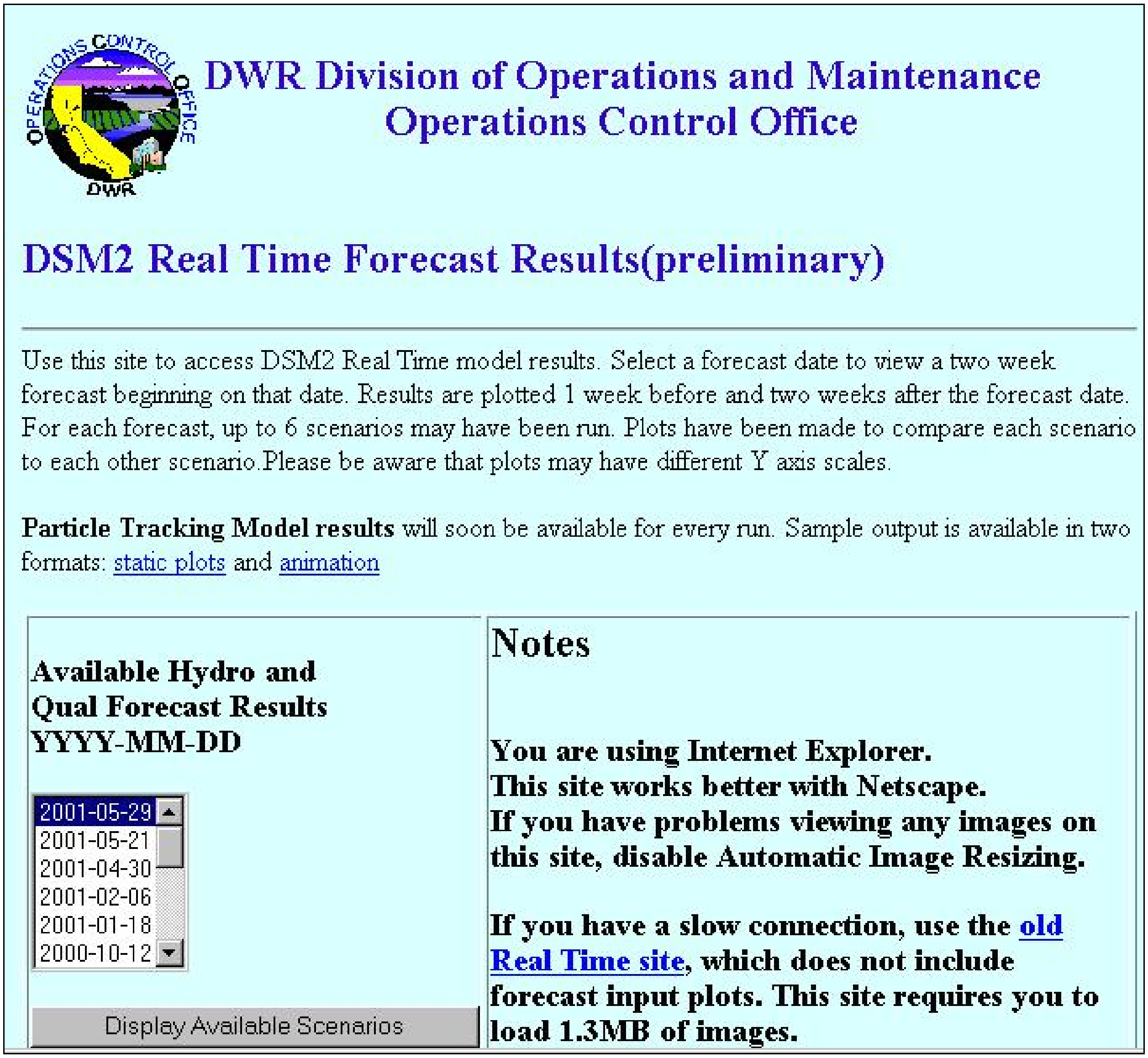


Figure 12-12: DSM2 Real-Time Forecast Results Web Page.

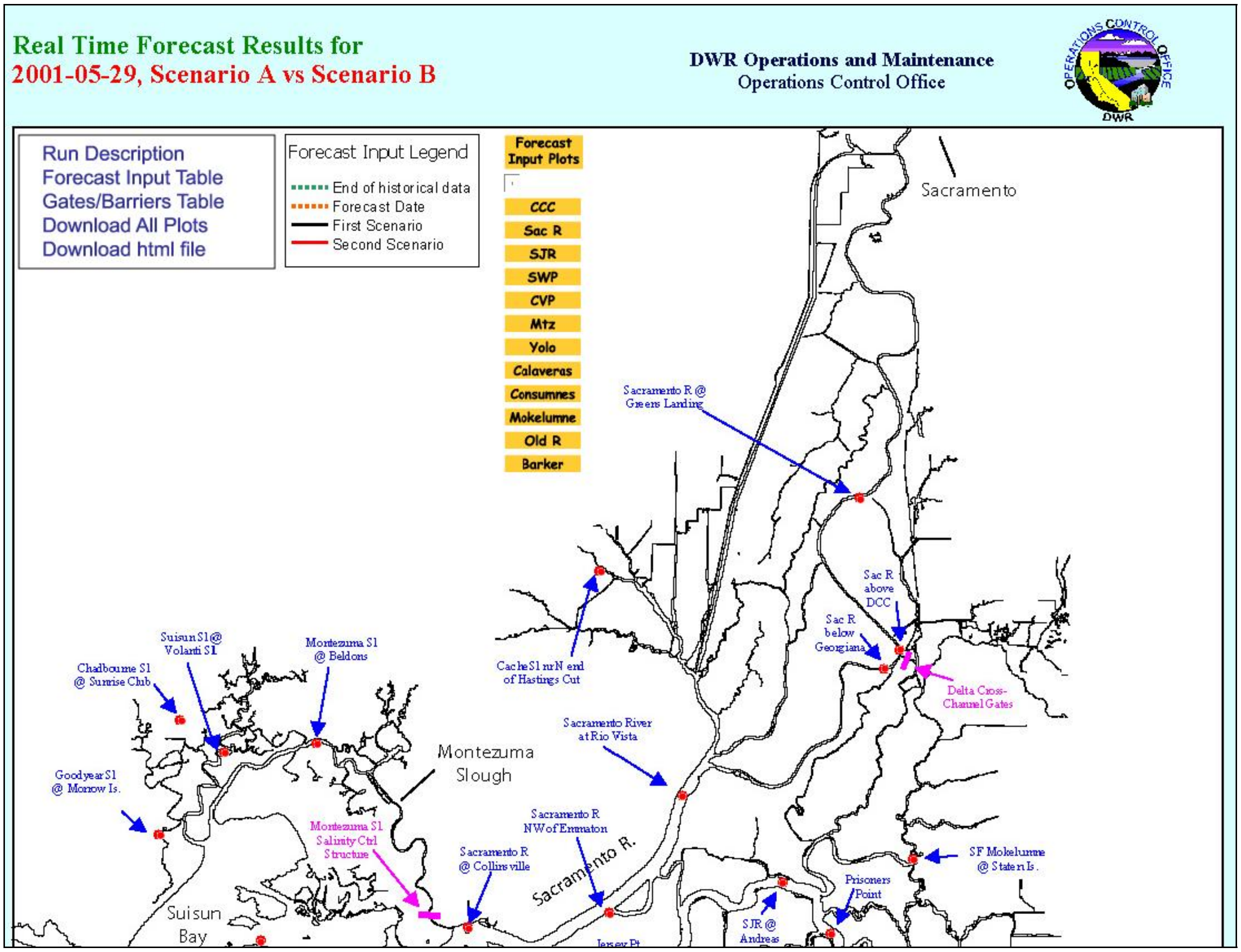


Figure 12-13: Interactive Delta Map to View HYDRO and QUAL Forecast Results.

The interactive map displaying HYDRO and QUAL results can be used to plot time series information about the inputs, as is shown below in Figure 12-14. Both the historical and forecast input data are shown on the same time series. In the example shown in Figure 12-14, there was no difference in the San Joaquin River flow between scenarios A and B. However, if there is a difference in the inputs between two scenarios, these differences will be displayed on these plots.

The same interactive map can be used to view instantaneous or tidally filtered flow, instantaneous or tidally filtered stage, and/or instantaneous or tidally filtered EC. By moving the cursor over a single location, the user can select which of the above time series plots to view as is shown below in Figure 12-15. All results from both scenarios and any observed field results will be plotted on the same time series.

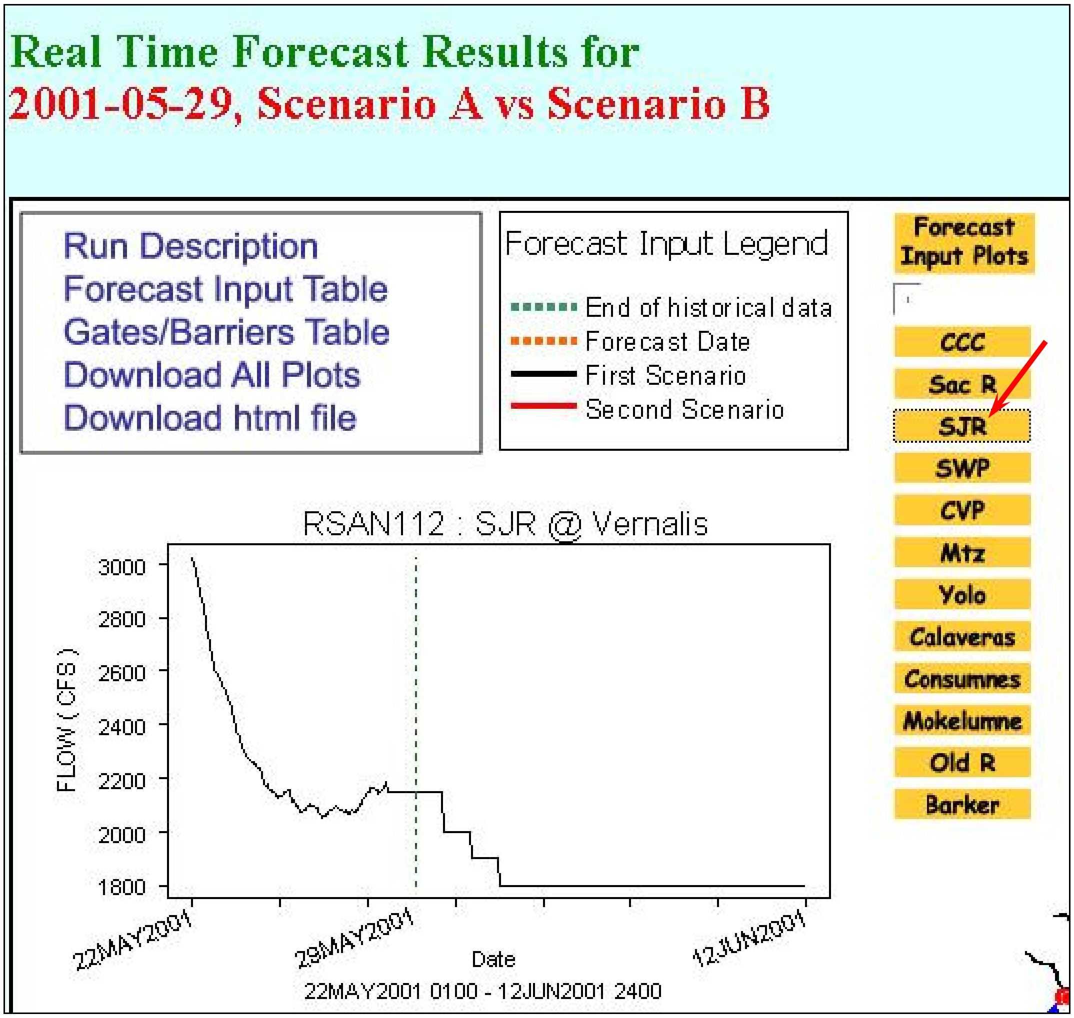


Figure 12-14: Viewing Forecast Input Results on Interactive Delta Map.

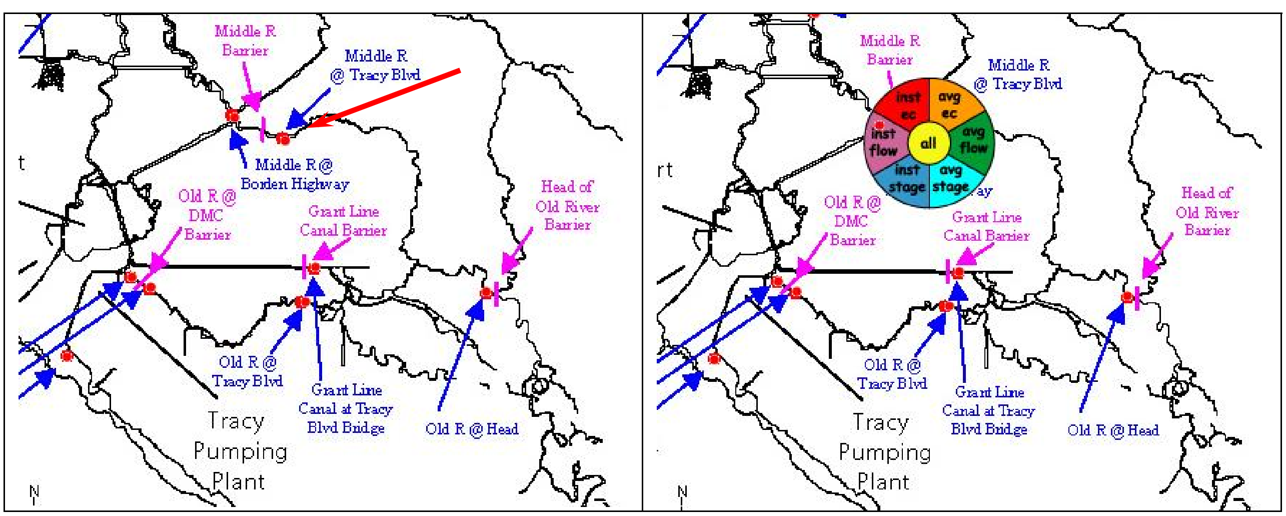


Figure 12-15: Selecting HYDRO and QUAL Results from Interactive Delta Map.

An example of the static PTM forecast results is shown below in Figure 12-16. When post-processing the PTM results, a static PTM plot can be printed once a day. Typically, these static PTM plots are created once every three to five days. The bars on the map represent injection locations. Each bar shows the particle fate for only particles released from that location.

For example, the bar highlighted in Figure 12-16 represents a particle injection location on the San Joaquin River. For this particular forecast, particles were injected into the Delta on June 1, 2001. The static plot shown displays the fate of all of these particles on June 29, 2001. As displayed in the bar, roughly one-third of the particles released on June 1, 2001 at this location ended up in the Central Valley Project, roughly one-third ended up being removed from the Delta via agricultural diversions, and the last one-third of the original particles released were still in the Delta.

For the first few days after the initial release, the majority of the bars will show most of the particles as still being within the Delta. As the particles move in the Delta, they will be exposed to both agricultural diversions and any other export/diversion activities under way. The particles that are listed as passing Chipps Island are considered to have left the Delta. Over time, the number of particles remaining in the Delta will decrease. A summary of the hydrologic information for a particular day shown is located in the upper left corner. Similarly, solid red bars are used to represent the placement of the South Delta barriers. If the barriers are not in place for a particular day, then no bars will appear on the static plot.

A static screenshot of the PTM dual animator is show in Figure 12-17. The PTM dual animator can be used to (1) observe the spatial distribution and movement of particles in the Delta and (2) compare the overall particle fate at the specified locations. Though the fate locations shown in Figure 12-17 were standardized for the DSM2 Real-Time Forecasting System, the number of particles animated and the locations reported can be changed.

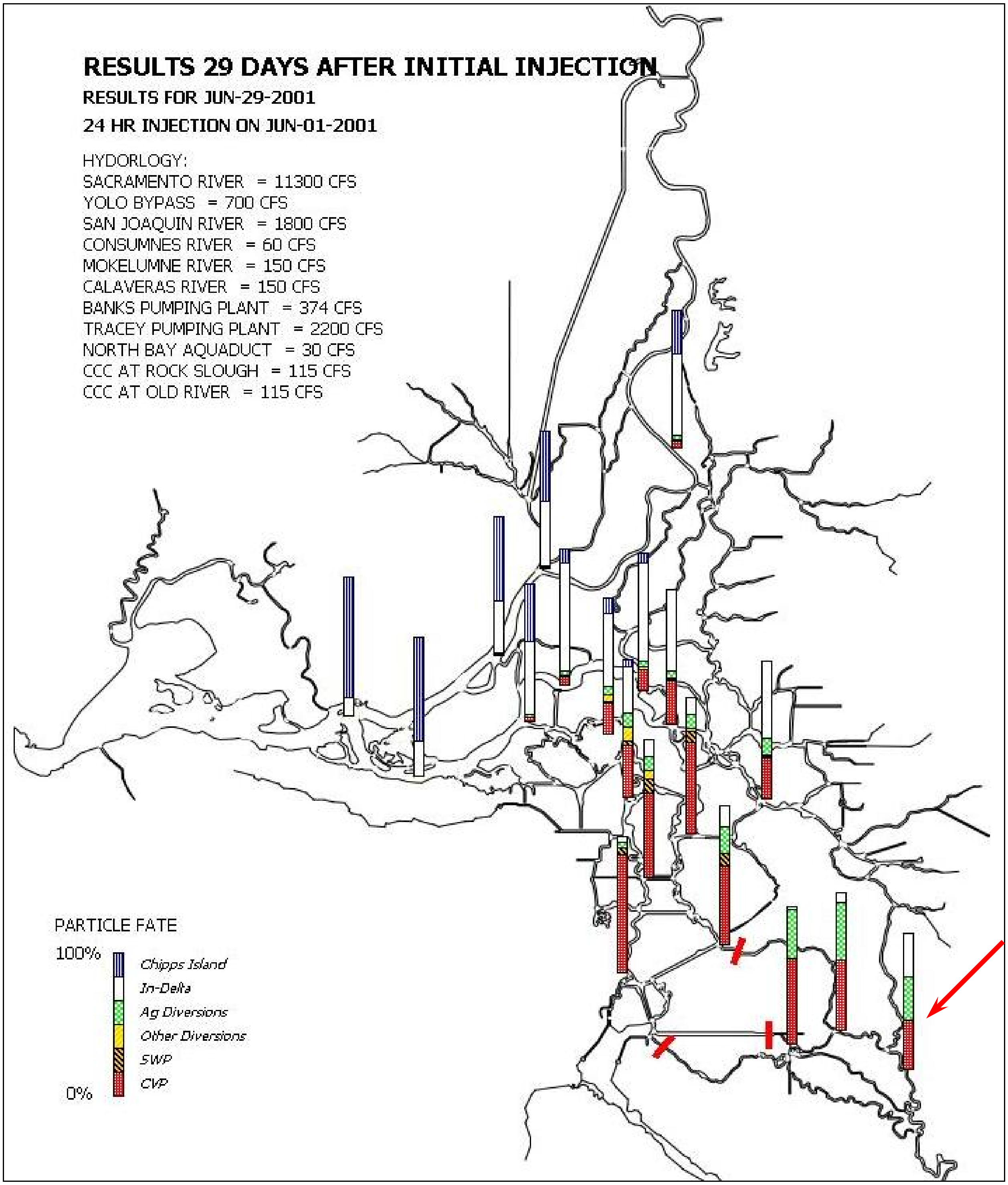


Figure 12-16: Static PTM Forecast Results.

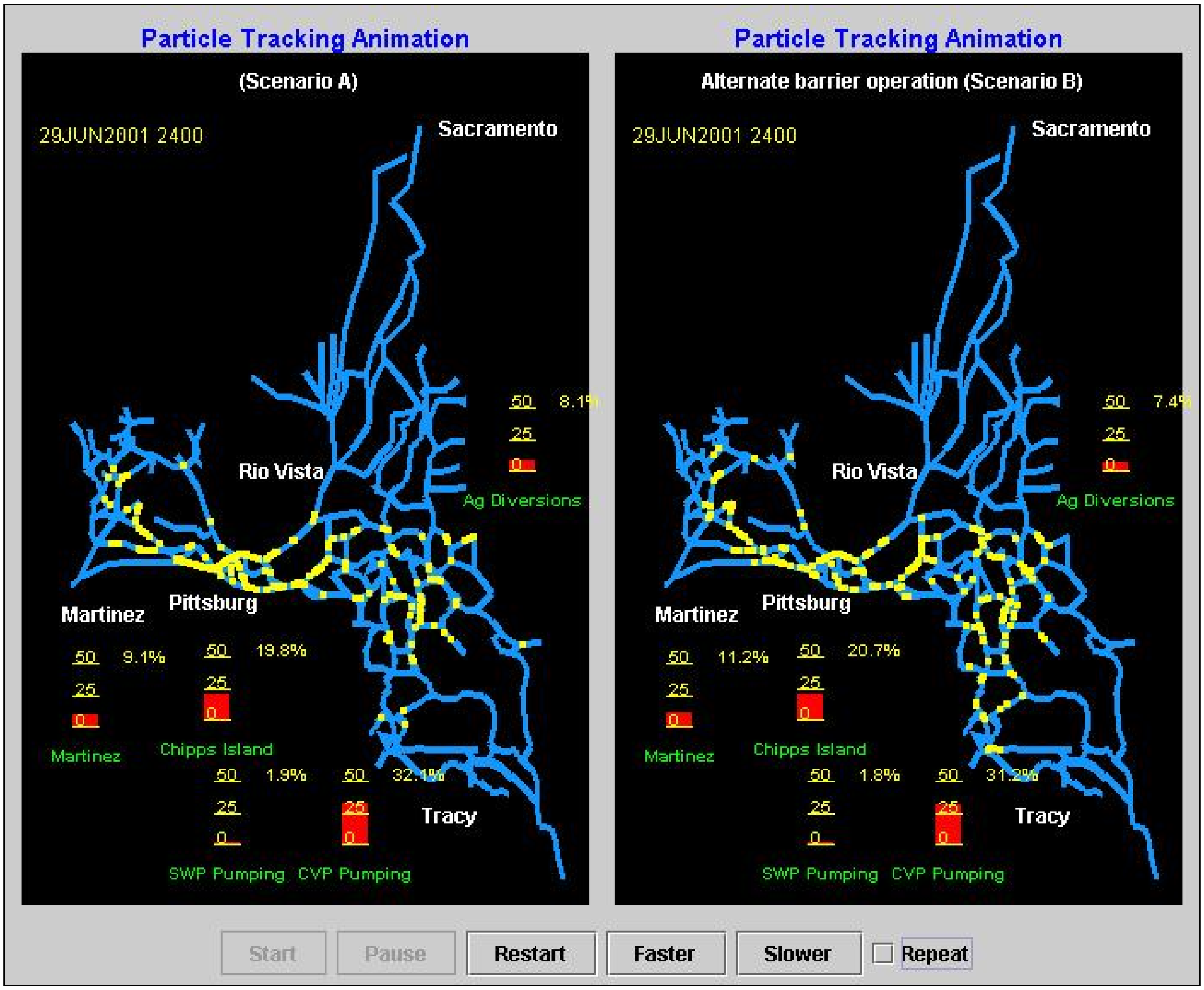
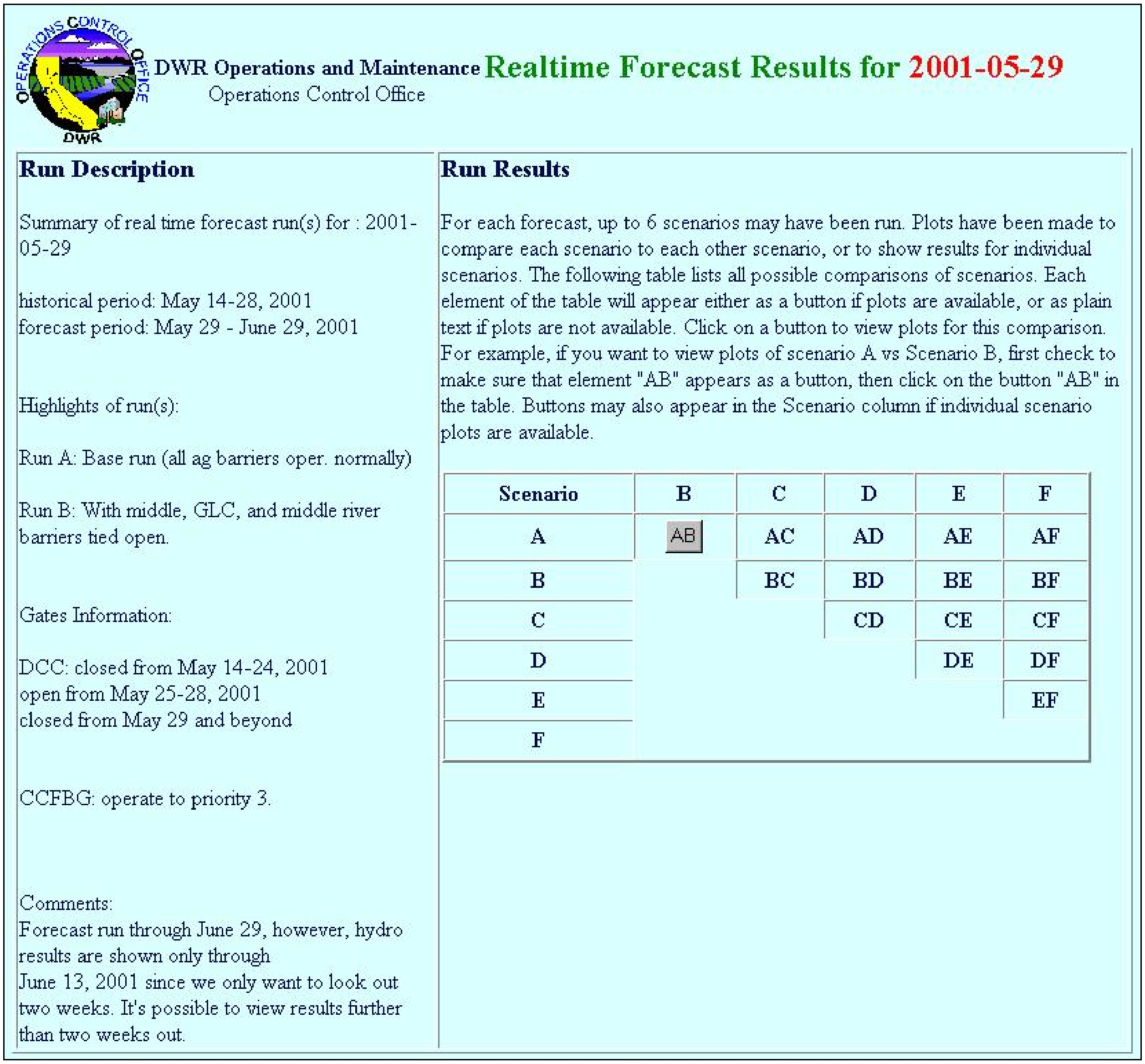


Figure 12-17: PTM Dual Animator.

12.4 Running Alternative Scenarios

The usefulness of DSM2 forecasts in decision support is not limited to running just a single base case scenario, but is also valuable in using the model to investigate the response to several alternative scenarios. The Web page results discussed above allow users to compare any two scenarios at the same time. For HYDRO and QUAL, these scenarios can be selected from a general menu where brief run descriptions of the results are also shown (see Figure 12-18).

Since any proposed operation will take place in the future, the same initial conditions that were developed for the base case can be reused for any alternative simulation. Though the pre-processing steps involved in calculating the warm start conditions or generating the historical flow values and gate operations will not need to be repeated, other steps that include both filling in and forecasting Martinez EC data will need to be repeated. Currently, there is no way to forecast Martinez stage based on planned changes in NDO, thus the base stage forecast will be used for all alternative scenarios. The MS Access Forecast Form can quickly create the input data for alternative flow regimes and gate operations. The steps involved in actually creating alternative scenario inputs using the MS Access Forecast Form are described at http://modeling.water.ca.gov/delta/real-time/foreform.html. Currently, the MS Access Forecast Form can not create alternative operations for: (1) the Clifton Court Forebay Gates, (2) the Delta Cross Channel Gates, and (3) the Montezuma Slough Salinity Control Gate. Presently, the model input for each of these three structures is created by hand.



DWR Operations and Maintenance Realtime Forecast Results for 2001-05-29
Operations Control Office

Run Description

Summary of real time forecast run(s) for : 2001-05-29

historical period: May 14-28, 2001
forecast period: May 29 - June 29, 2001

Highlights of run(s):

Run A: Base run (all ag barriers oper. normally)

Run B: With middle, GLC, and middle river barriers tied open.

Gates Information:

DCC: closed from May 14-24, 2001
open from May 25-28, 2001
closed from May 29 and beyond

CCFBG: operate to priority 3.

Comments:
Forecast run through June 29, however, hydro results are shown only through
June 13, 2001 since we only want to look out two weeks. It's possible to view results further than two weeks out.

Run Results

For each forecast, up to 6 scenarios may have been run. Plots have been made to compare each scenario to each other scenario, or to show results for individual scenarios. The following table lists all possible comparisons of scenarios. Each element of the table will appear either as a button if plots are available, or as plain text if plots are not available. Click on a button to view plots for this comparison. For example, if you want to view plots of scenario A vs Scenario B, first check to make sure that element "AB" appears as a button, then click on the button "AB" in the table. Buttons may also appear in the Scenario column if individual scenario plots are available.

Scenario	B	C	D	E	F
A	AB	AC	AD	AE	AF
B		BC	BD	BE	BF
C			CD	CE	CF
D				DE	DF
E					EF
F					

Figure 12-18: Comparing Scenarios When Using On-line Results.

When creating alternative scenarios, it is recommended that only one operational parameter be changed at a time. For example, if several hypotheses are to be tested in DSM2, including changes in the export levels, operation of the Delta Cross Channel, and inflows of the major tributaries, separate scenarios should be created to test the impact of each of these proposed operations. This type of scenario extends into the timing of operations as well. The Delta is highly sensitive to both the operation of barriers/gates and to the levels of inflows and exports. Delaying the installation/removal of a barrier or altering inflows/exports for just one week can make the difference between having a significant impact on stage or water quality versus seeing no immediate response in the Delta. The MS Access Forecast Form minimizes the effort involved in creating a “delayed” scenario.

While the DSM2 Real-Time Forecast System is robust enough to create alternative scenarios, the primary concern focuses back on the amount of information end users need and how much of that information can be presented in a timely fashion. Although there is no fixed limit to the number of alternative scenarios that can be produced in short order, the current on-line results are limited to displaying up to six different scenarios (including the base). Obviously, DSM2 can be used to run more than six scenarios; however, there is a practical limit to providing decision makers with too many alternatives to discuss in a short meeting.

12.5 Conclusions

Although the DSM2 Real-Time Forecasting System described here is currently in use by various DWR groups, it is still being developed. The majority of the current work is related to both improving the visualization of the model results and establishing a more reliable institutional framework that can support weekly forecast runs.

Collecting real-time raw data will continue to be a critical task. Issues related to phase shifts due to the change from Pacific Standard Time (PST) to Pacific Daylight Time (PDT) need to be resolved between the various agencies that collect field data and the end users of their data. Furthermore, raw field data were shown to serve as a valuable quality assurance/quality control tool. When post-processing model results, the ability to go back and look at the performance of the model at locations away from the boundary locations is important.

It is possible to reduce the amount of time required by the modeler to pre-process the raw data by reducing the number of visual confirmations involved in both downloading the raw data and later confirming that filled-in data look appropriate. However, due to the importance of the decisions that are being made based on these DSM2 results and the tenuous nature of raw data, the quality of completely automated modeling results could not be achieved without relying on frequent checks of both the raw and processed data. Since the “what if” questions that are asked of the DSM2 Real-Time Forecasting System are done during the forecast period, the historical data only need be screened once. Furthermore, if forecasts are run at frequent intervals, the extent of the historical data that have not been screened will decrease as the frequency of pre-processing the raw data increases.

It is important to think of this forecasting tool not as a series of scripts and computer models, but instead to recognize that it is, in fact, a true systems engineering process. The time involved in actually running DSM2 is minimal compared to all of the other work involved. Essentially, there are three main parties that must interact:

- Providers of the raw data,
- Users of the raw data/providers of the model results, and
- Users of the model results/decision-makers.

The breakdown of one process will have a direct impact on the functioning of all the other processes. Furthermore, as the various providers/users work together on a more frequent basis, the system itself can change to meet the immediate needs of the final end users, the decision-makers. In other words, the system needs to remain flexible enough to answer all of the questions originally proposed in the introduction.

Regular forecasts force the users of the raw data (modelers) to constantly keep in touch with the raw data providers. Should a real-time telemetered monitoring station cease reporting data, or if a station starts to report data that is obviously wrong, the amount of data that is lost during this down period would be less if the data are being regularly examined. It is the responsibility of the data providers to educate the modelers on how the data are obtained from the field and how they are stored. Similarly, it is the job of the modelers to clearly prioritize their data needs.

Model results themselves are another form of unprocessed data. By regularly attending decision making meetings, numerical modelers can not only provide better insight into the assumptions that were made during the forecast, but they also can get a better understanding of the needs of the decision makers. Though the results of the models should be presented in a way that the modeler who processed the raw data and ran the model need not be present, new questions will be asked of both the model data and the model itself. Modelers are responsible for educating decision makers about what their models can do. And, decision-makers need to not only communicate their questions clearly, but they should feel free to consider more than one planned alternative at a time.

Realistically, the timing of changes in gate operations or the hourly flows at the rim boundaries will never be exactly what was modeled. So, the model results should not be considered absolute. DSM2 is a decision analysis tool and is most useful when it is viewed as a trend analysis tool. By asking several “what if” operational questions and running them all based on the same initial conditions, the different modeled responses to these proposed operations can be compared to one another.

12.6 Future Directions

The DSM2 Real-Time Forecasting System is a work in progress. Some of the work currently in progress was discussed above in addition to some of the future needs of this forecasting tool. The following is a short list of this continued effort.

- Improving the MS Access Form to allow modelers to enter in the operational status of the Clifton Court Forebay Gates, the Delta Cross Channel Gates, and of the Montezuma Slough Salinity Control Gate.

- Incorporating into the MS Access Form the ability to quickly compute forecast changes to the Net Delta Outflow Index. This will allow the existing pre-processing scripts to quickly compute the EC at Martinez for all alternative simulations.

- Make use of (if available) any new real-time stage, flow, or EC monitoring stations for Quality Assurance/Quality Control. When new real-time data become available, the pre- and post-processing scripts will be updated to incorporate this data.

- Continuing to develop user friendly tools to widely distribute forecast results.

- Performing weekly base case forecasts (and adding additional scenarios to the base forecast when necessary).

- Continue to maintain and update the on-line documentation, http://modeling.water.ca.gov/delta/real-time/. A specific "Frequently Asked Questions" section is being developed to assist model users any time there is a problem with a simulation. This documentation has already been used to convert the tools designed for this application of DSM2 to other DSM2 applications. In the future, parts of this documentation can be used for DSM2 training.

- Encourage additional groups outside DWR to both use the forecast results (in addition to encouraging greater use of DSM2 outside DWR). This includes having DSM2 modelers working closer with both data providers and decision-makers.

- Changing how DSM2 simulations affect the Clifton Court Forebay Gates. Currently, DSM2 models all the gates as being either opened or closed. There are five gates at the entrance to the forebay, each of which operates independently from the rest. Improving DSM2's treatment of the gates will allow the model to be used for sensitivity studies for periods when one or more of the gates is under repair or otherwise not functioning.

- Develop more appropriate estimates for the Delta Island Consumptive Use (DICU). Currently, the Delta Modeling Section updates the historical DICU data once a year, and no work has been done to come up with forecast DICU data. One plan would be to create several consumptive use "bookends" that represent high and low levels of agricultural diversions and/or returns. Sensitivity studies could then be used to estimate better forecast DICU data.

12.7 References

Ateljevich, E. (2000a). "Chapter 8: Filling In and Forecasting DSM2 Tidal Boundary Stage." *Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh. 21st Annual Progress Report to the State Water Resources Control Board.* California Department of Water Resources. Sacramento, CA.

Ateljevich, E. (2000b). "Chapter 11: DSM2-QUAL Initialization." *Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh. 21st Annual Progress Report to the State Water Resources Control Board.* California Department of Water Resources. Sacramento, CA.

Sandhu, Nicky. (2000). "Chapter 4: VPlotter." *Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh. 21st Annual Progress Report to the State Water Resources Control Board.* California Department of Water Resources. Sacramento, CA.